Shaking Table Tests of Full-Scale Rocking Selective Pallet Racks

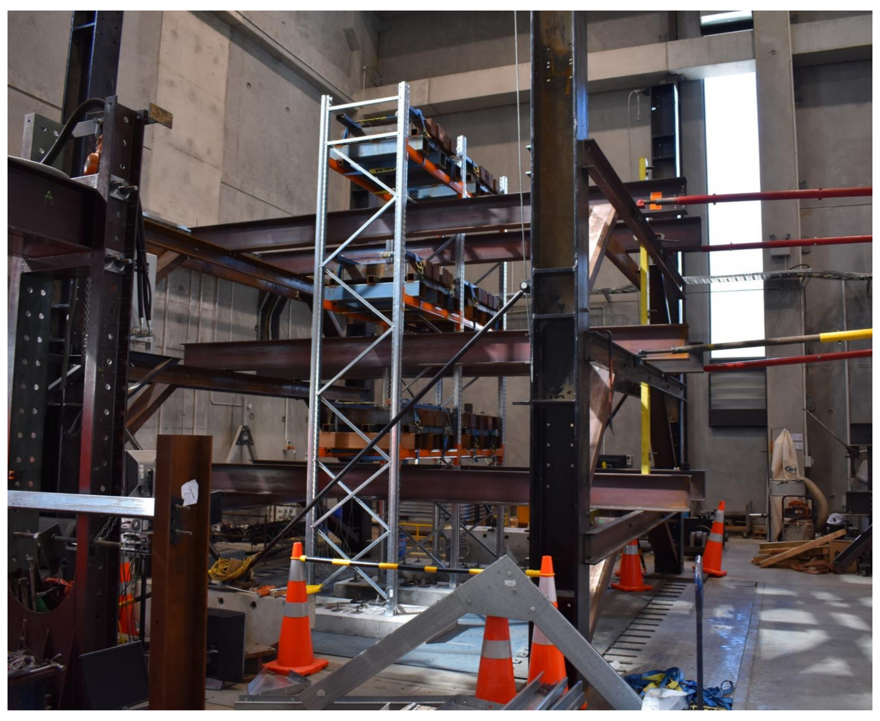
J.R. Maguire[1,2], Z. Tang[2,1], G.C. Clifton[2], L.H. Teh[1], J.B.P. Lim[2]

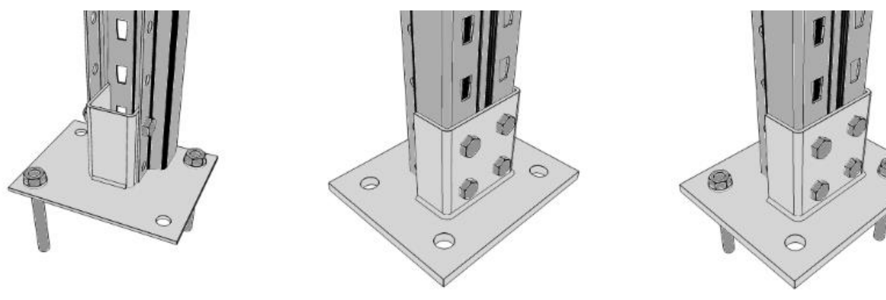
[1]University of Wollongong, [2]University of Auckland

Introduction

A series of full-scale shaking table tests were conducted at the University of Auckland Structures Test Lab. Three complete structures were tested in the cross-aisle direction, each with a different baseplate type: ductile, unanchored, and rigid (the former two allowing uplift and rocking response).

The experiment aim was to determine the benefit, if any, of allowing the structure to rock in the cross-aisle direction. This was done by observing the rack displacement and upright axial loading up to the structural failure.





a) Ductile **b)** Unanchored **c)** Rigid

Figure 1. Baseplate types

Table 1. Shaking table test sequence

	Record	Scale Factor	% Design Level	Baseplate type: Ductile	Unanchored	Rigid
1	Kaikoura, 2016	0.617	25%	✓	✓	✓
2	Kaikoura, 2016	1.234	50%	✓	✓	✓
3	Kaikoura, 2016	1.851	75%	✓	✓	✓
4	Kaikoura, 2016	2.468	100%	✓	✓	✓
5	Northridge, 1994	0.988	100%	✓	✓	✓
6	Kobe, 1995	0.983	100%	✓	✓	✓
7	Northridge, 1994	1.235	125%	✓	✓	✓
8	Kobe, 1995	1.475	150%	✓	✓	✗ Baseplate bolt pull out
9	Northridge, 1994	1.482	150%	✓	✗ Rack overturning	
10	Kobe, 1995	1.966	200%	✓		
11	Northridge, 1994	1.729	175%	✓		
12	Kobe, 1995	2.258	230%	✓		

Test setup

A three-level selective rack with two half-bays was tested for each of the three test series. All six pallet bays were loaded with an 8 kN welded steel pallet. The pallets were clamped to the rack beams with two ratchet straps to prevent sliding.

A row of three concrete foundation blocks was clamped to the shaking table, and the rack baseplates were anchored down using masonry anchor screws. The unanchored baseplate was not anchored but was prevented from "walking" in the shaking direction with a set of shear blocks.

The shaking table allowed a single-axis of motion with a displacement range of +/- 200 mm. A steel catch frame was in place, allowing the rack to be tested to failure while not interfering with the rack response.

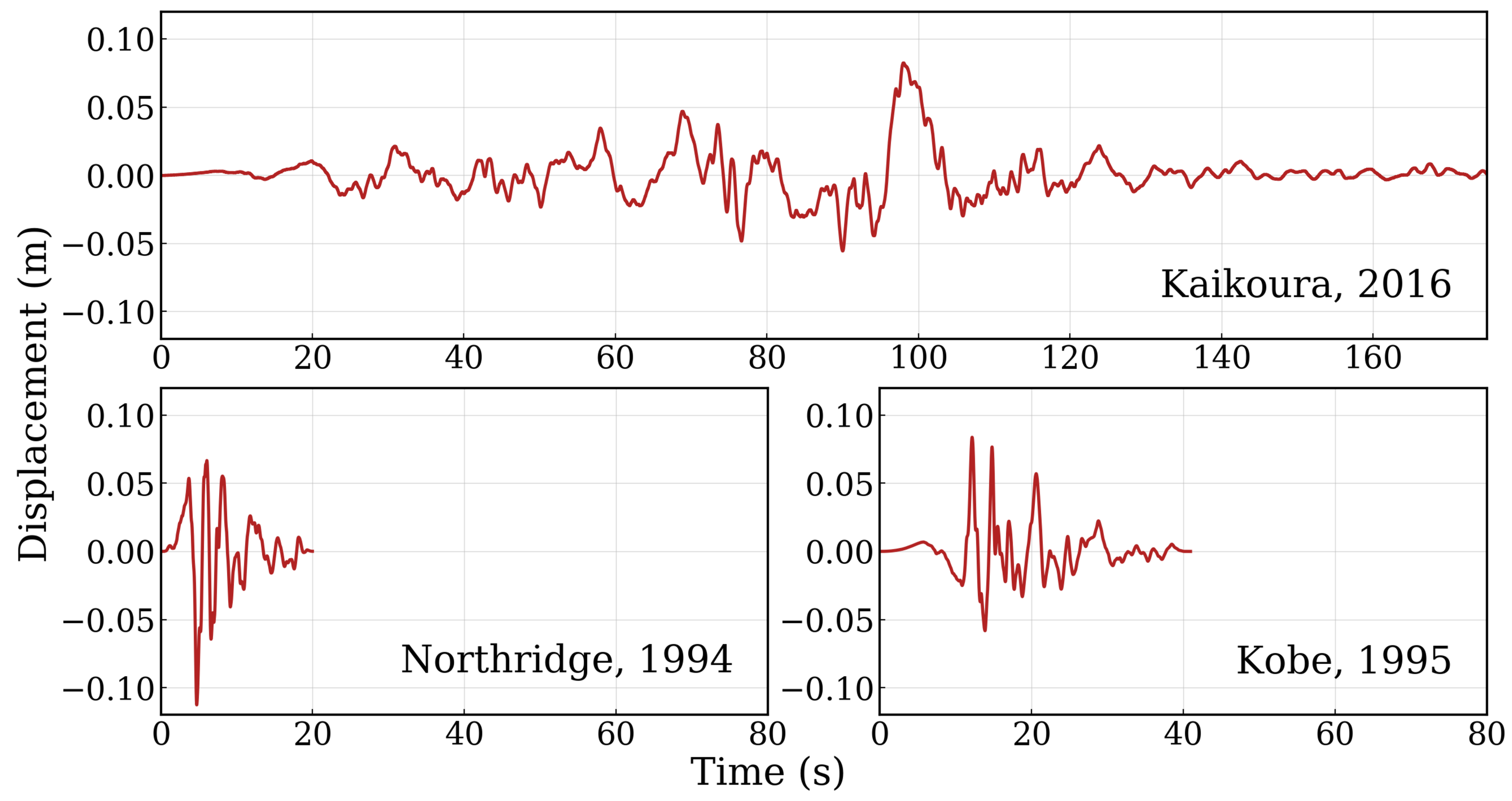


Figure 2. Ground motions *(at scale-factor = 1.0)*

Ground motions

Each rack was subjected to a sequence of ground motions, shown in Table 1. The selected motions, Kaikoura 2016, Northridge 1994, and Kobe 1995, were chosen as a suitable fit to the target spectra when scaled (Figures 2/3).

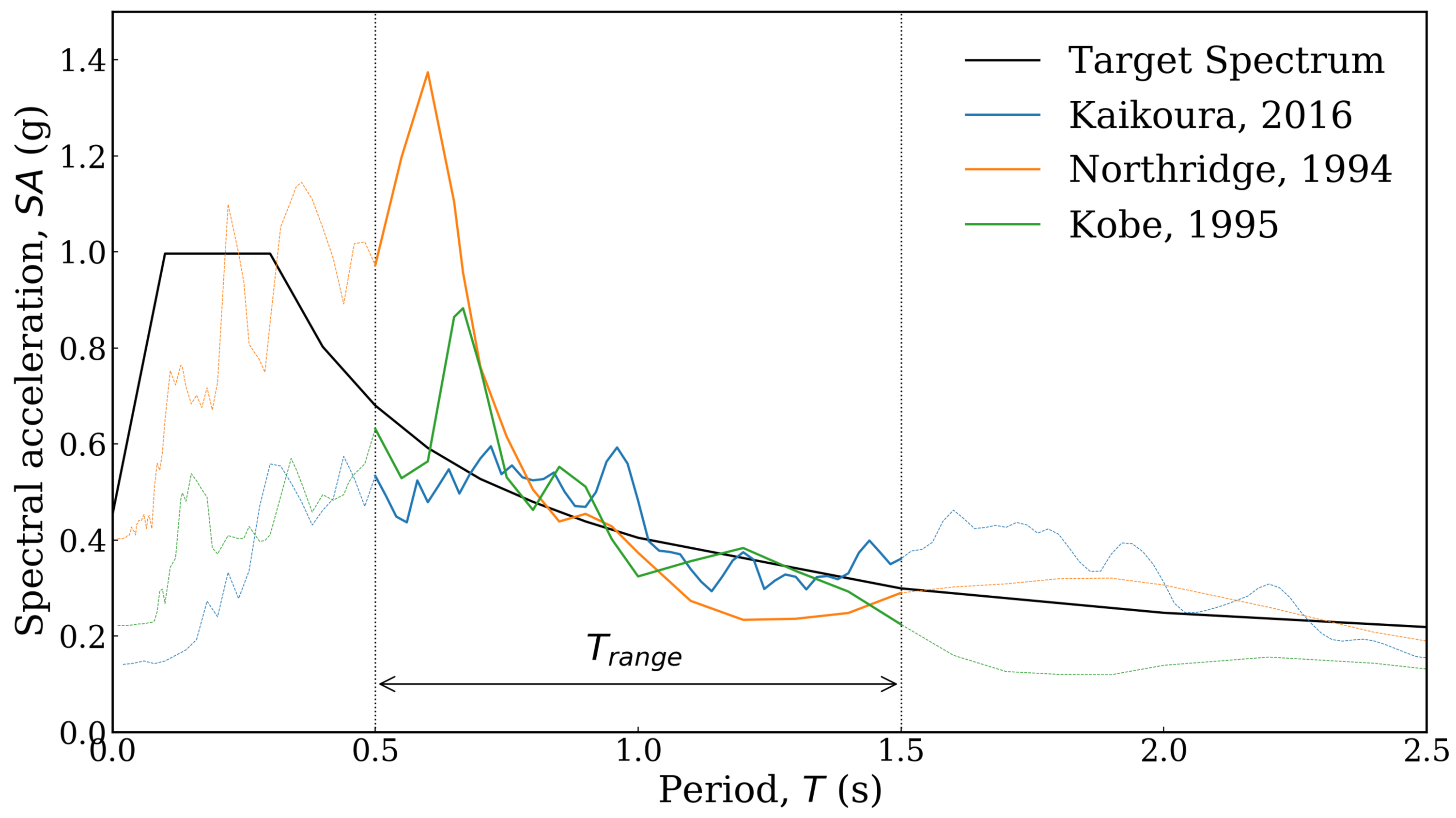


Figure 3. Scaled ground motion spectra

Bolt pull out of rigid baseplate

Overturning of unanchored baseplate

Results

All baseplate types survived up to the design level earthquake. The unanchored and the rigid baseplates failed at 150% the design level earthquake but on different ground motions. The ductile baseplate survived all motions up to 230% (limit of the shaking table).

It is seen in Figure 4 that the stiffer baseplates resulted in higher axial loading of the uprights. High axial loading resulted in a bolt pull out failure of the rigid baseplate. The unanchored baseplate acted as a base isolator, keeping the axial force within the range of 0-22 kN (compression), but the large displacements led to overturning failure.

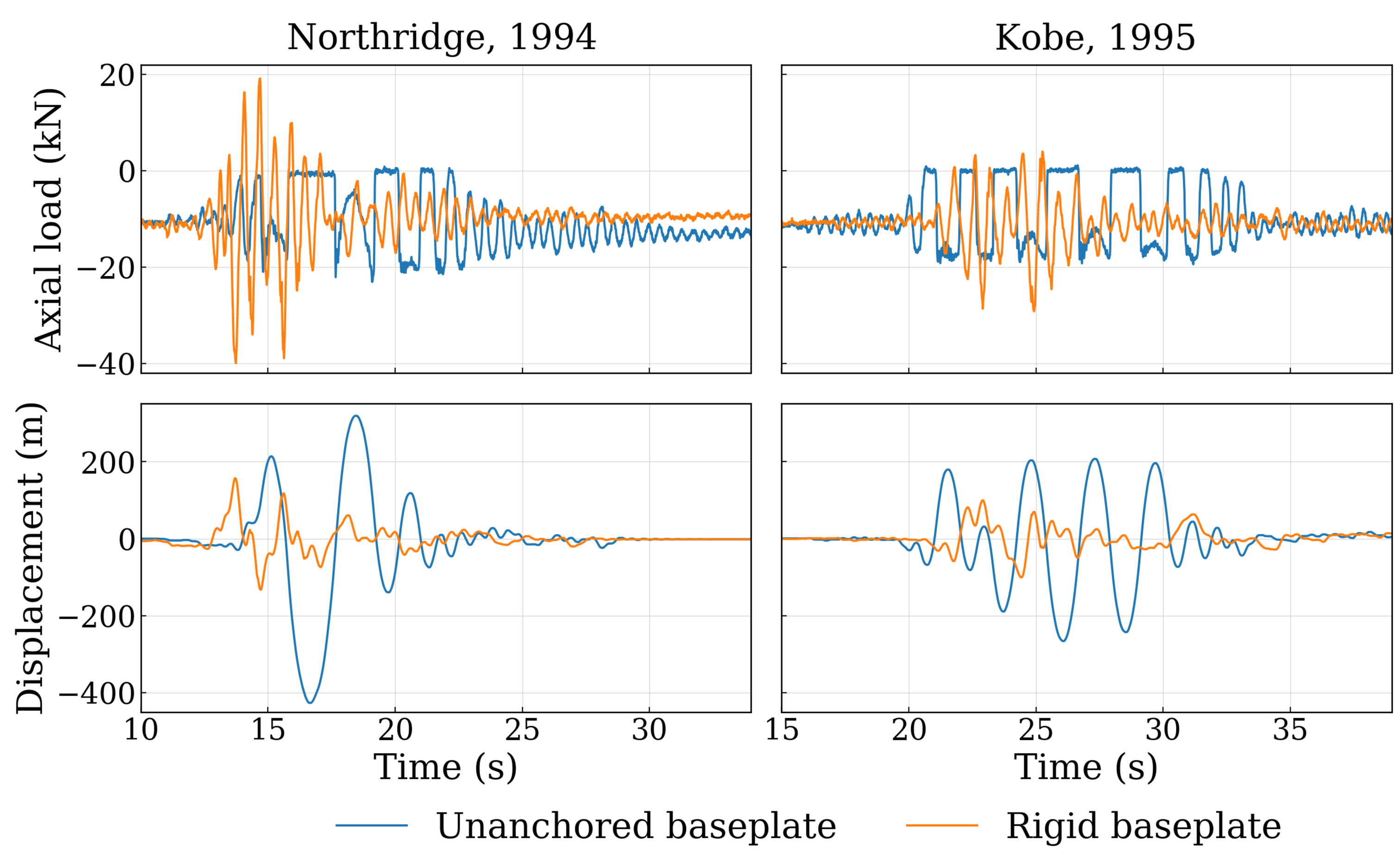


Figure 4. Response of unanchored and rigid baseplates to Northridge and Kobe ground motions

Conclusions

1. Structure response is sensitive to ground motion characteristics, especially for lower stiffness and unanchored baseplates.
2. Stiff baseplates are likely to exceed foundation uplift capacity or frame buckling capacity in design.
3. The ductile baseplate provided the best performance under repeated and varying ground motions.

Contact information

James Maguire University of Wollongong

E jrm978@uowmail.edu.au **M** +61 467 364 847

UNIVERSITY OF WOLLONGONG AUSTRALIA

THE UNIVERSITY OF AUCKLAND Te Whare Wānanga o Tāmaki Makaurau NEW ZEALAND

Acknowledgements

Funding provided by QuakeCoRE and Australian Government Research Training Program Scholarship